Correlation of fundamental plasma parameters with EUV emission profiles of laser-produced Sn plasmas for EUV lithography light sources

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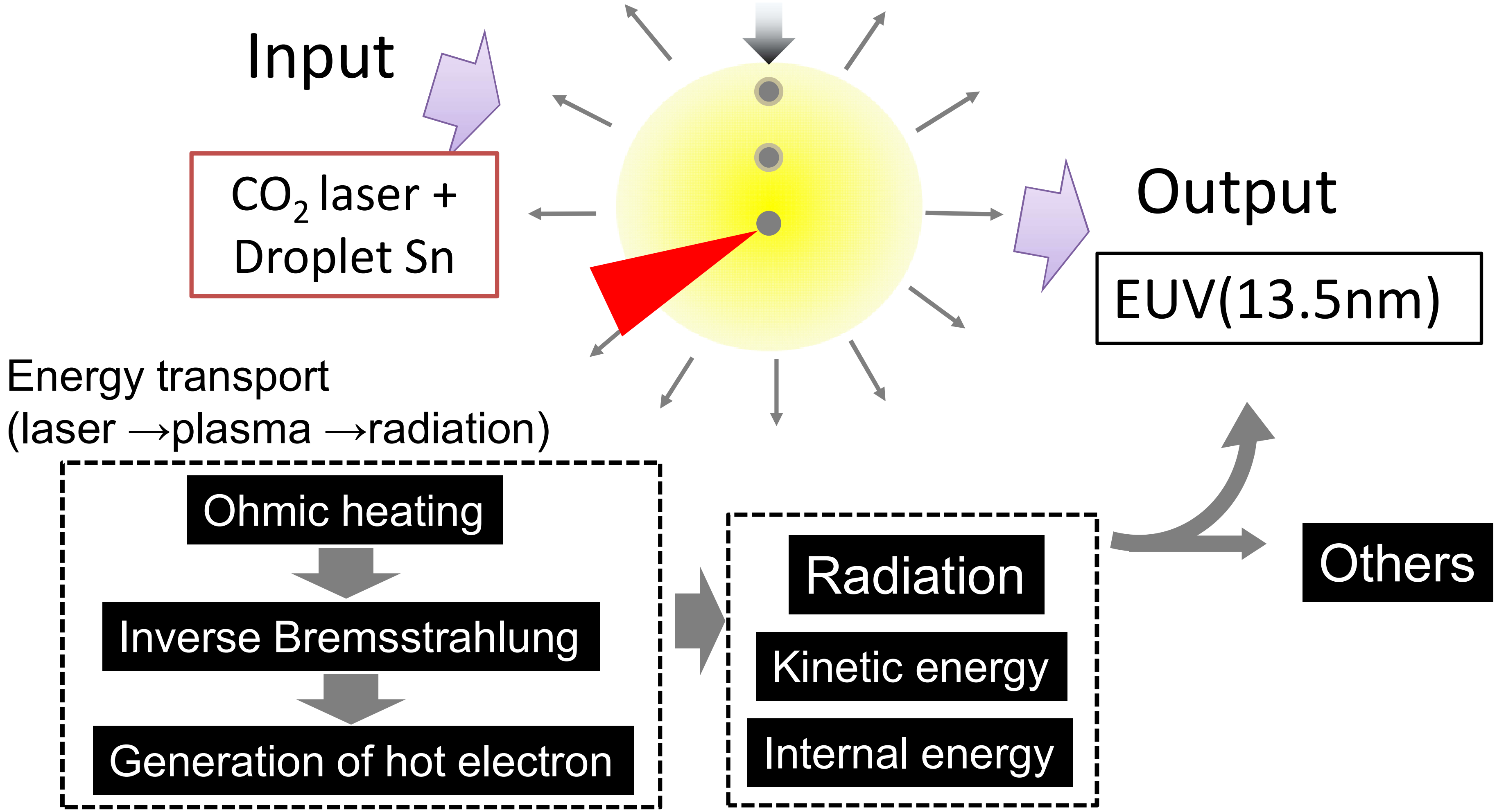
GIGAPHOTON

Problems

To practical use of EUV … Debri reduction, Improvement of operation rate, …

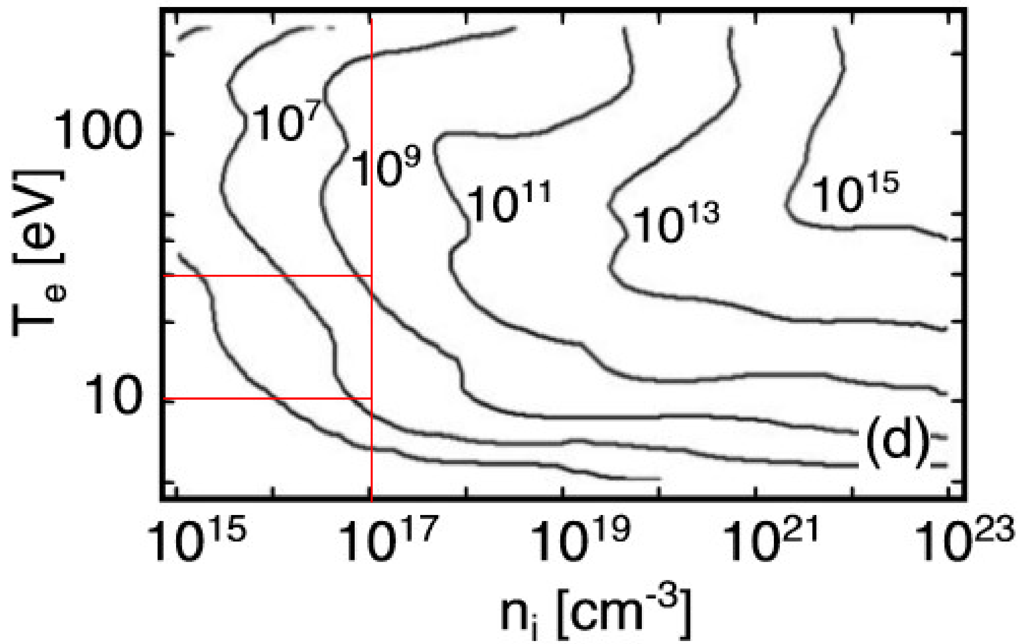
> 250 W @ 13.5 nm

Improve conversion efficiency (Input laser to EUV) is necessary



Important plasma parameters

Optimized Sn plasma is,,,,
Electron density: $n_e = 10^{24} - 10^{25}\ m^{-3}$
Electron temperature: $T_e \sim 30 - 50$ eV
Averaged Ionic charge: $Z \sim 10$



A. Sasaki et al., J. Appl. Phys. (2010)

Fig. 15 (d) Calculated in-band emissivity (W cm-3)

10eV, 30eV

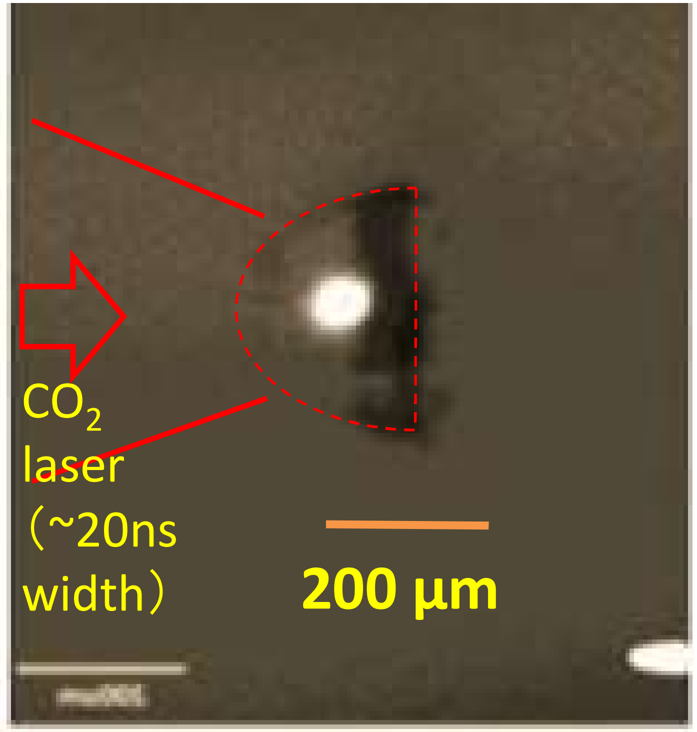
100 times different

Measurements and controlling Te is most important!

Method required for EUV plasmas

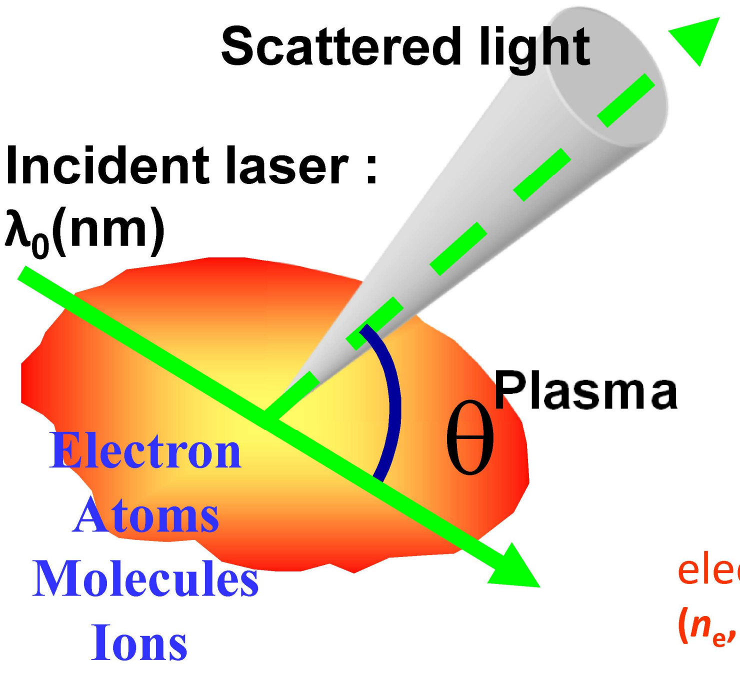
- Spatial resoution（≦50 μm）
- Temporal resolution （≦ 5 ns）
- Te, ne, Z

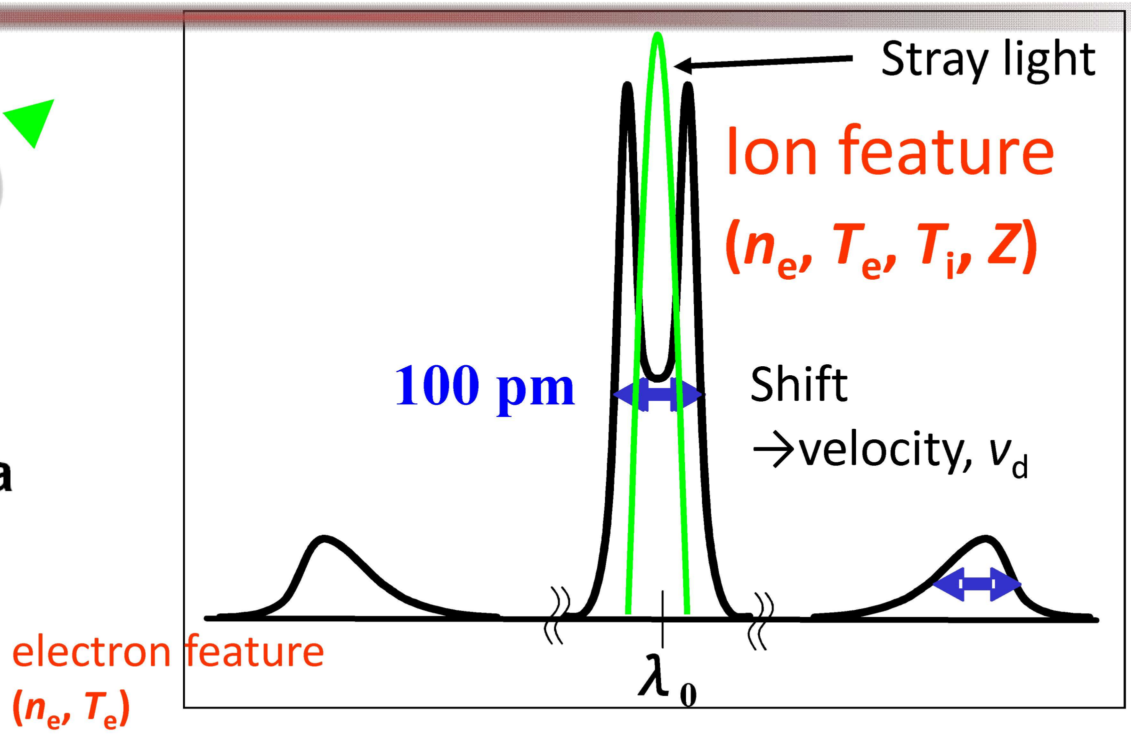
Laser scattering diagnostics



Shadow of expanded Sn target

Method ; Laser Thomson scattering





For Discharge EUV: E. R. Kieft et al., Rev. Sci. Instrum. 76, 093503 (2005)

Intensity → $\sim n_e$

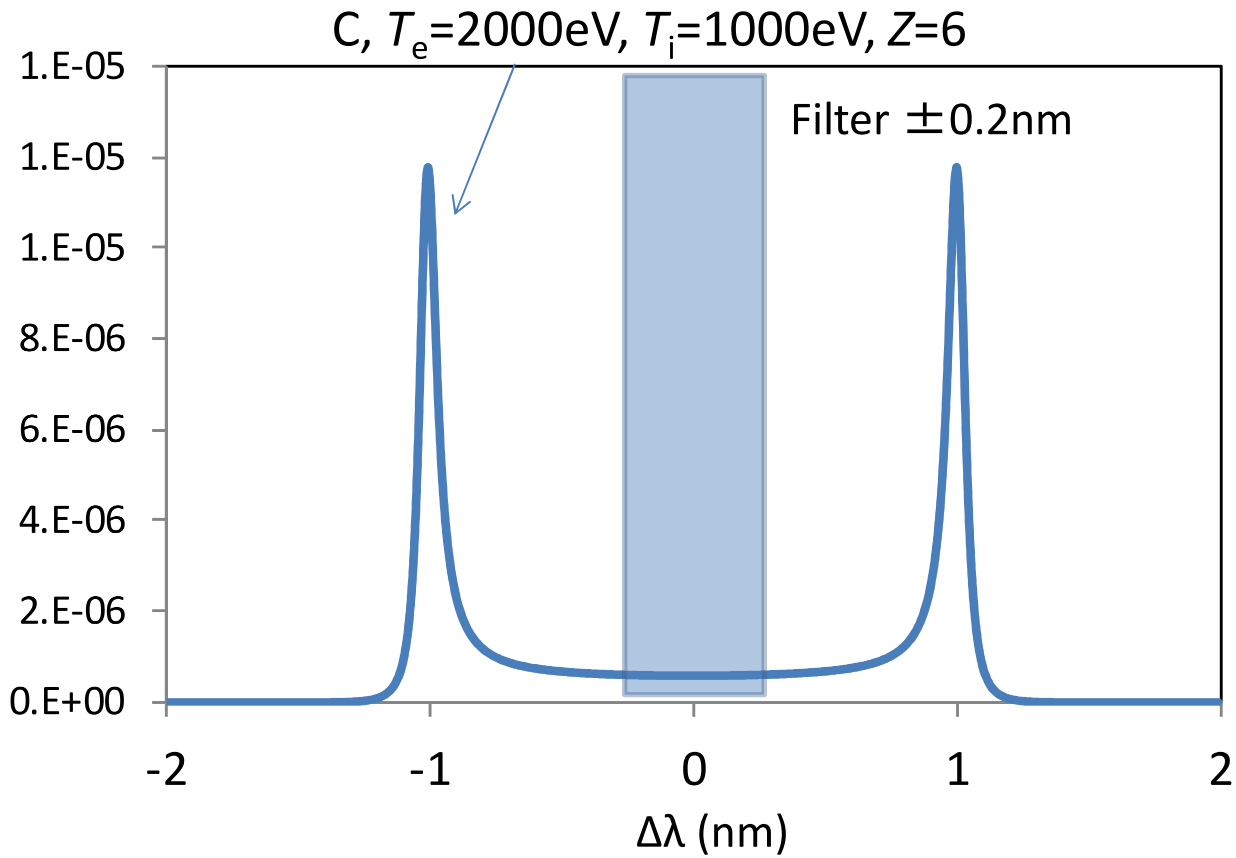
Spectral width → $T_e\, T_i\,, Z$

Spectral shape → $Z,\ T_e,\ T_i$

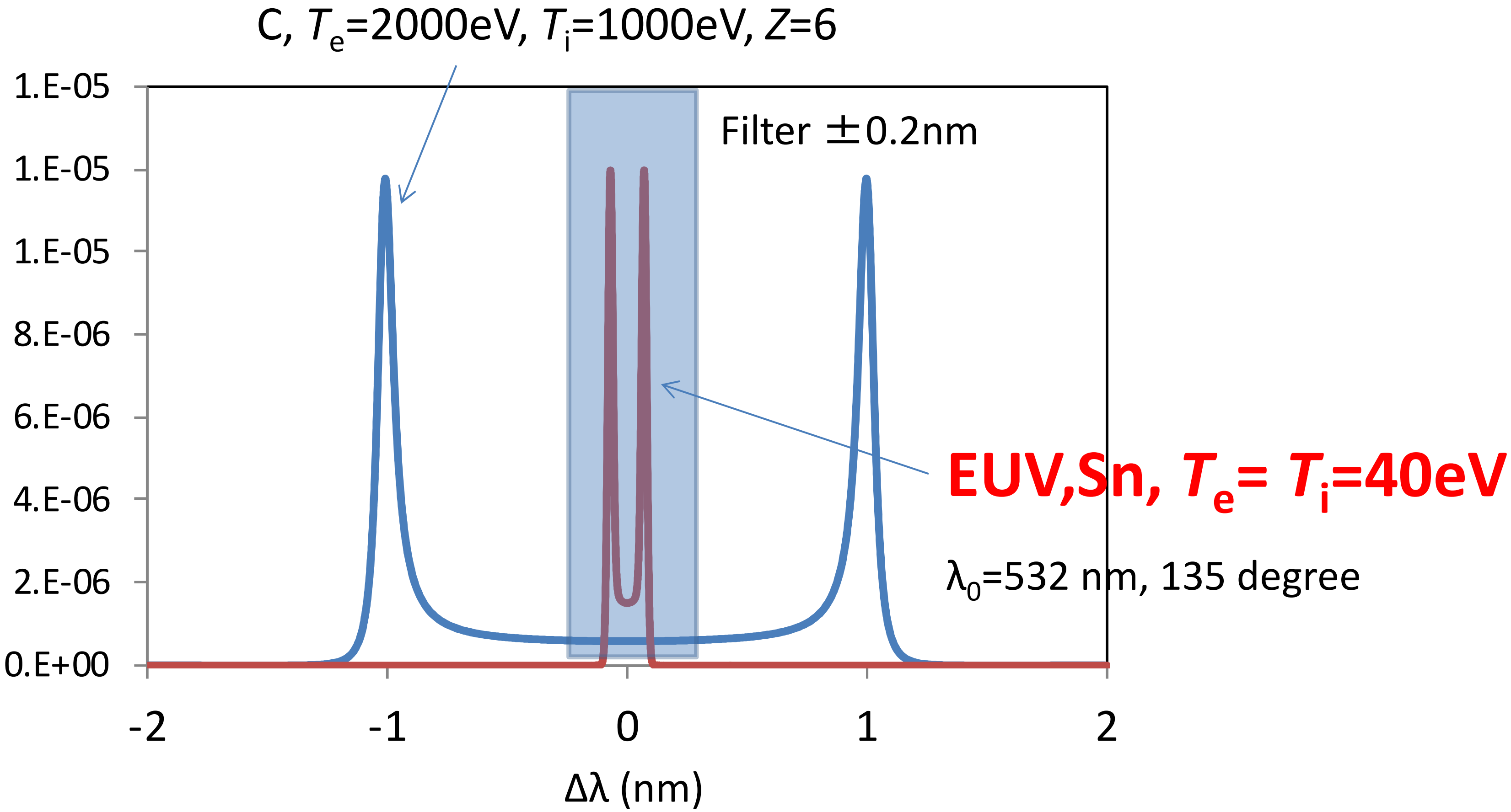
→ $n_e,\ T_e\,,\ Z$

Shift →velocity, v_d

Difficulty of Thomson scattering for EUV plasmas



Difficulty of Thomson scattering for EUV plasmas



Ion feature measurements

high spectral resolution (~20 pm),

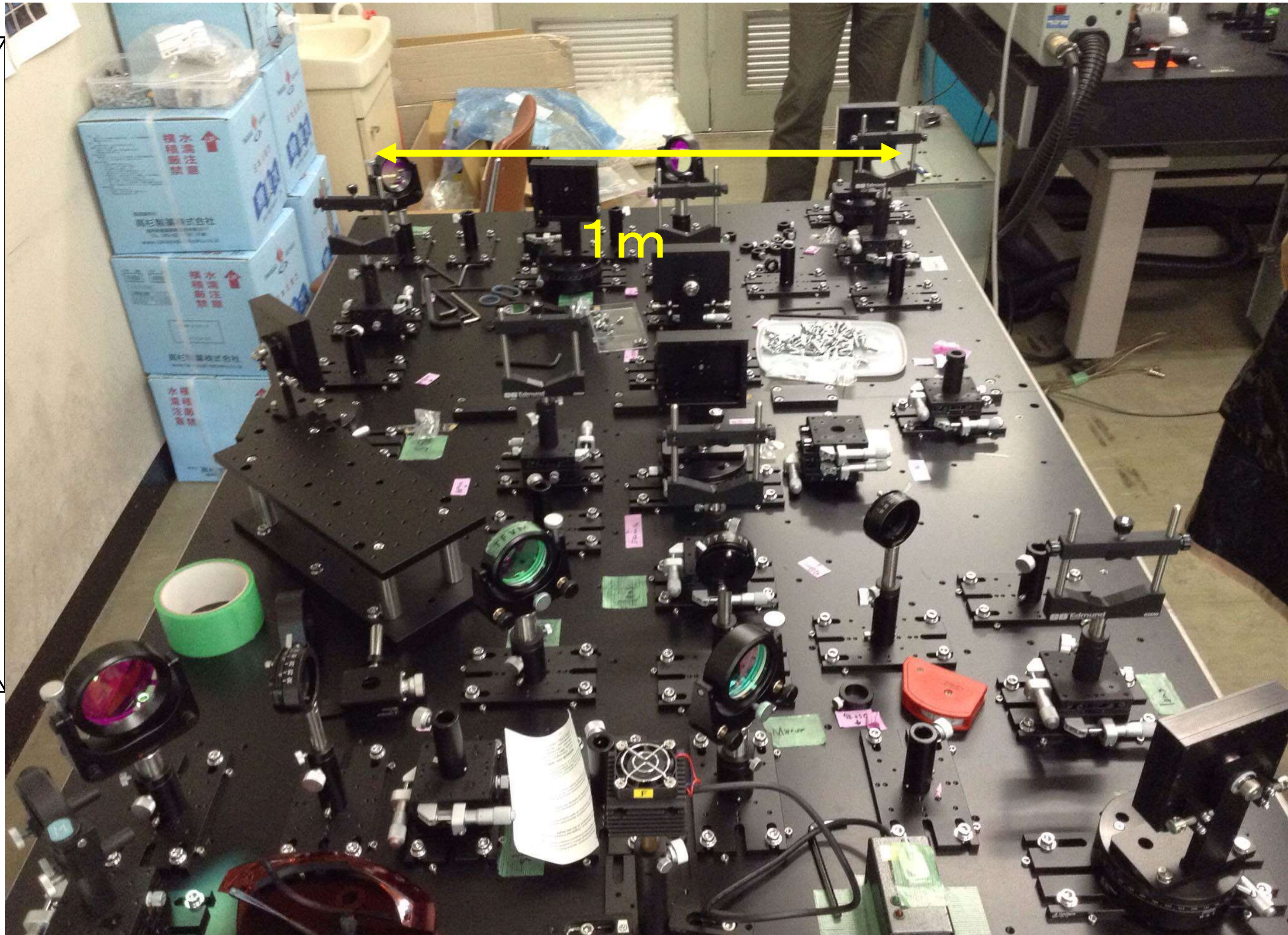
sufficient stray light rejection (stray light from target material)

Cut only near laser wavelength (< 0.02nm)

Development of LTS system for Sn plasmas

To overcome problems…

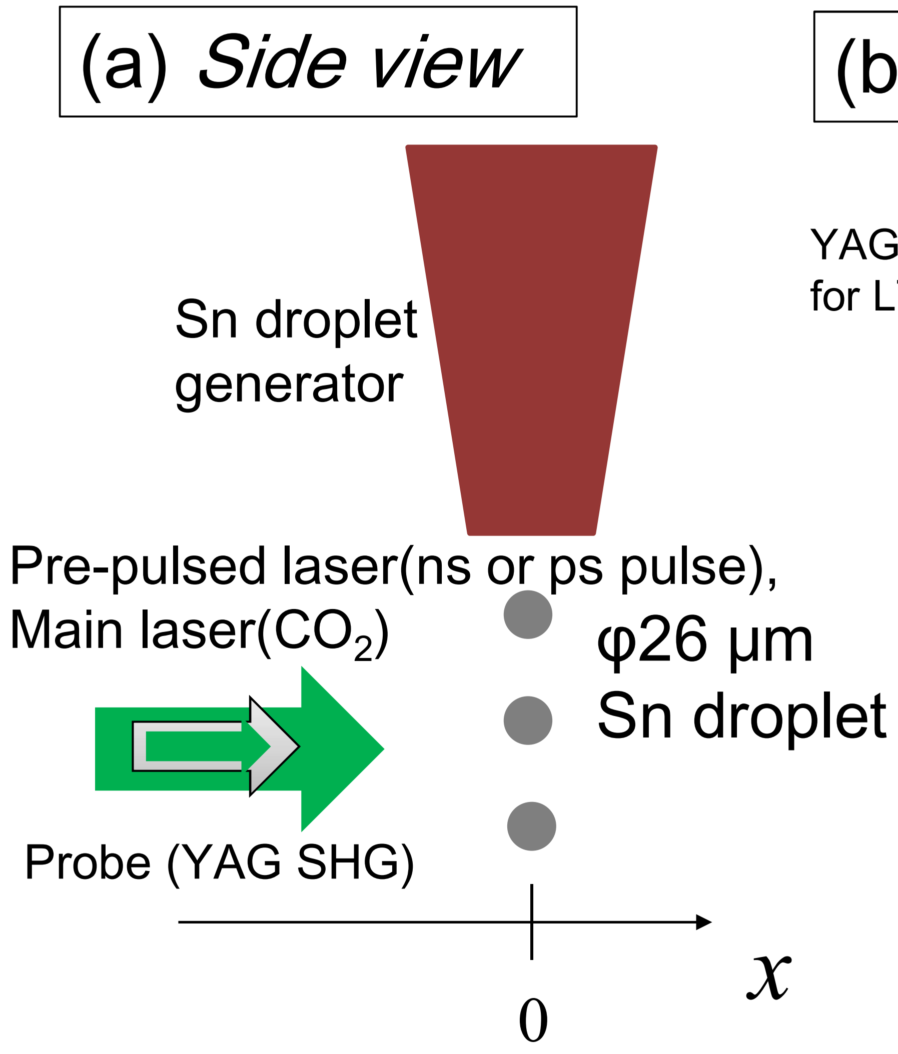
1 m

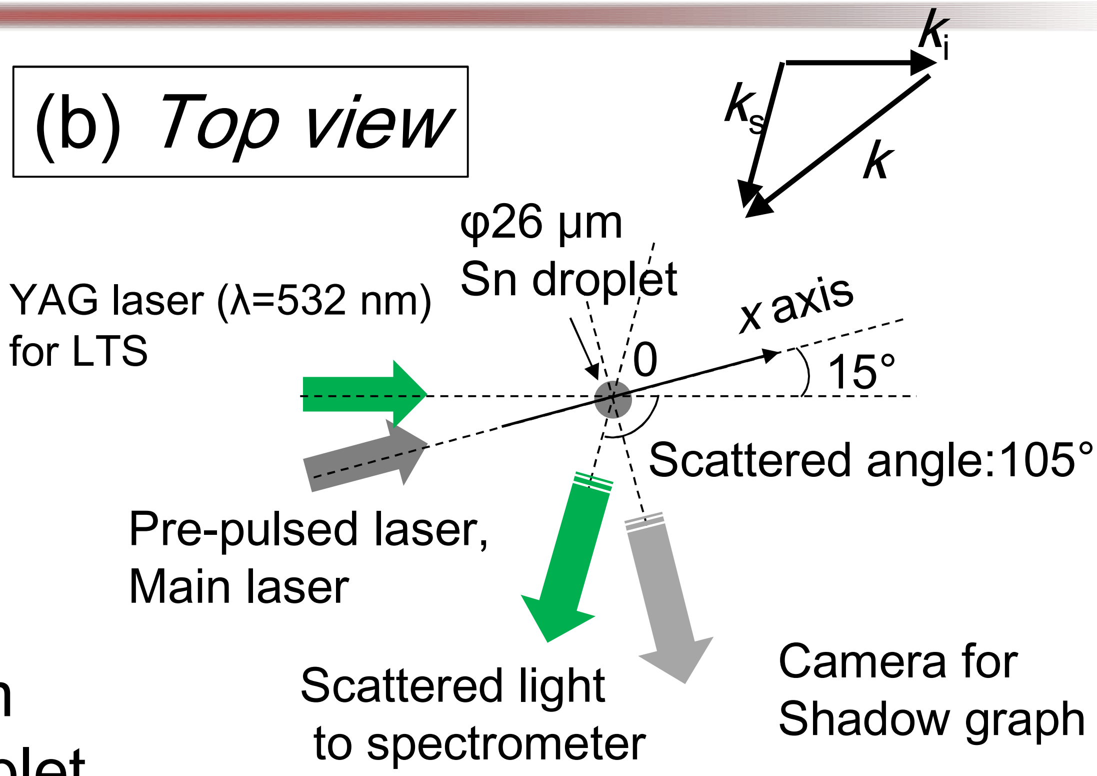


C)

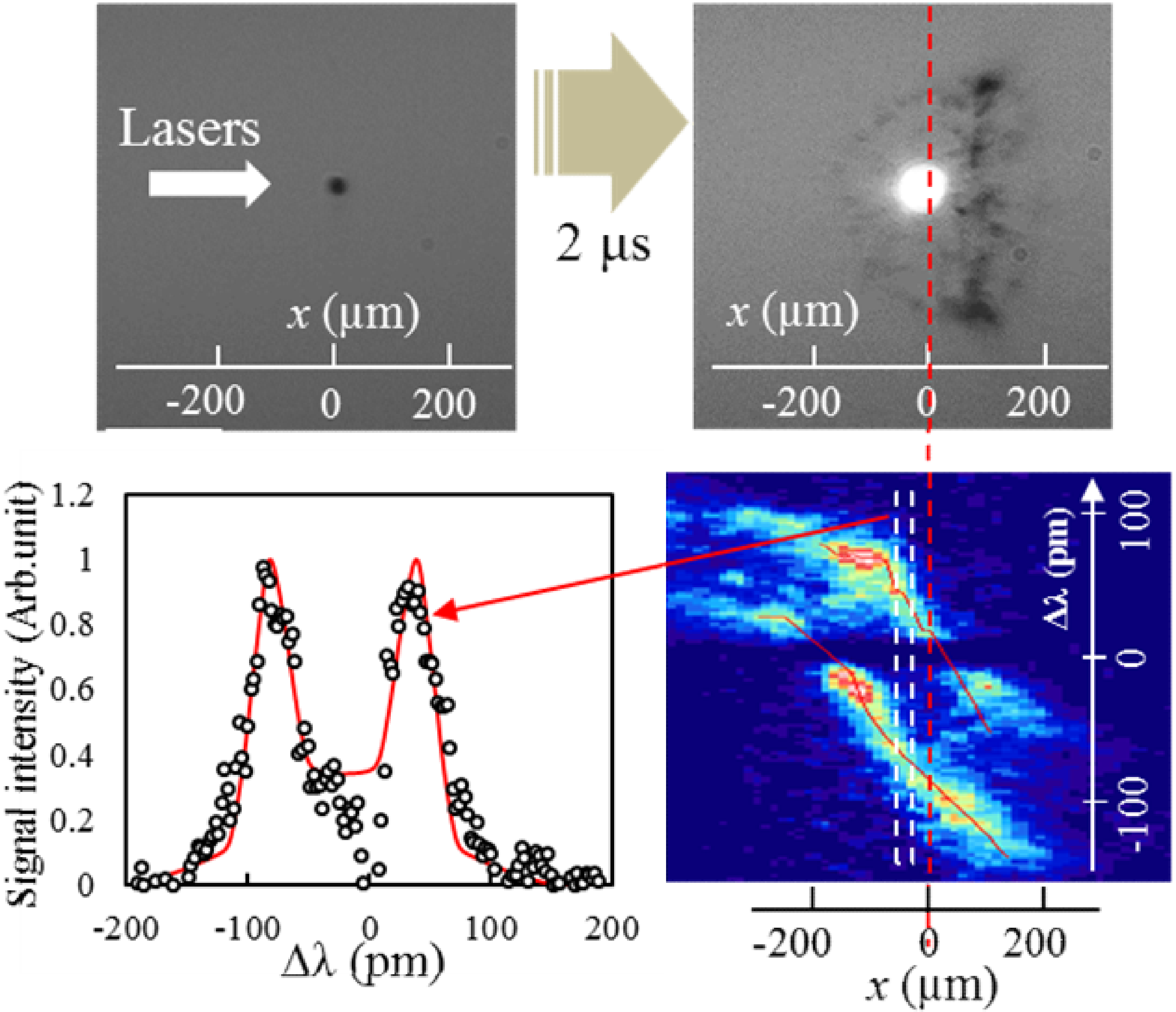
Spectral resolution : 10 pm

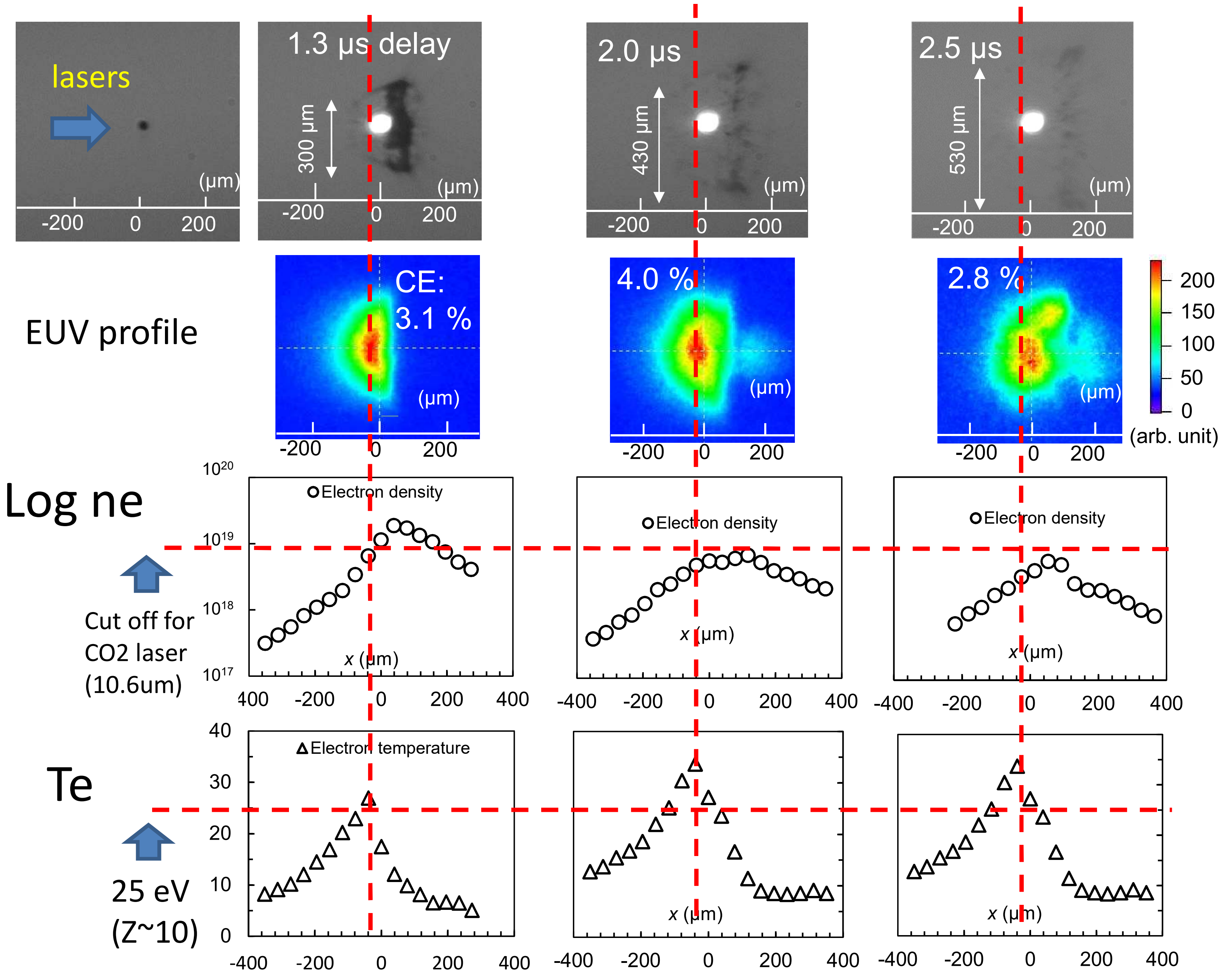
Experimental setup for EUV Sn plasma





Results of LTS





lasers
1.3 μs delay
300 μm
2.0 μs
430 μm
2.5 μs
530 μm
(μm)
-200
0
200
EUV profile
CE:
3.1 %
4.0 %
2.8 %
(arb. unit)
Log ne
Electron density
Cut off for
CO2 laser
(10.6um)
x (μm)
Te
Electron temperature
25 eV
(Z~10)

Conclusion

1. A new LTS system for laser-produced EUV light sources has been developed. n_e, T_e, Z, and v_d, along the probing laser path, has become possible.
2. By using this LTS system, the structure of laser-produced Sn droplet plasmas for EUV light sources was clarified as the spatial profiles of n_e and T_e.
3. LTS was performed for EUV plasmas, whose CEs ranged from 2.8-4.0%. Results clearly showed that intense EUV emissions were obtained from positions corresponding to sufficiently high Te values and Z > 10. This experimental fact is consistent with previous simulation studies.